



Satellite images for offshore wind resources

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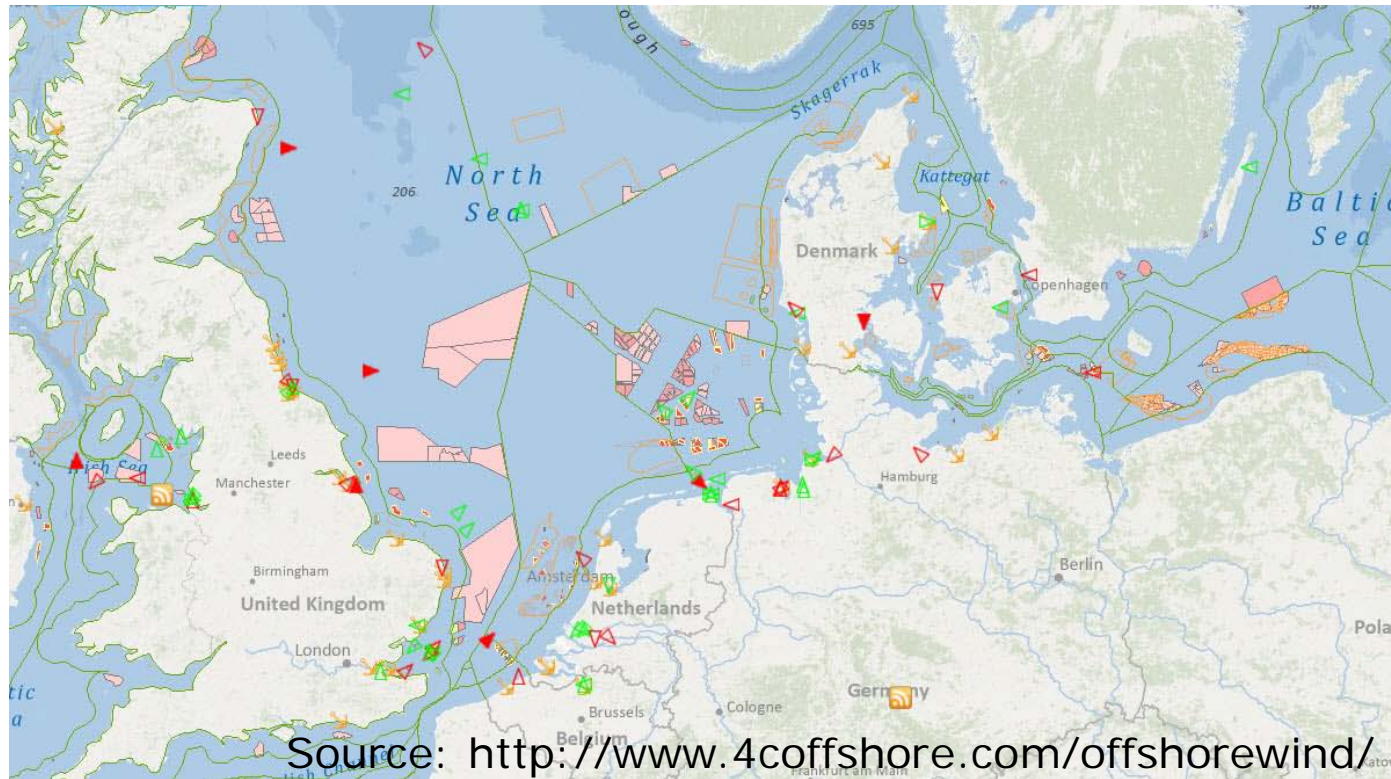
Satellite images for offshore wind resources

Charlotte Bay Hasager, Merete Badger, Ioanna Karagali, Ferhat Bingöl,

Content

- Motivation
- Ocean wind from satellites
- Wind resources offshore
- Wind farm wake
- Summary

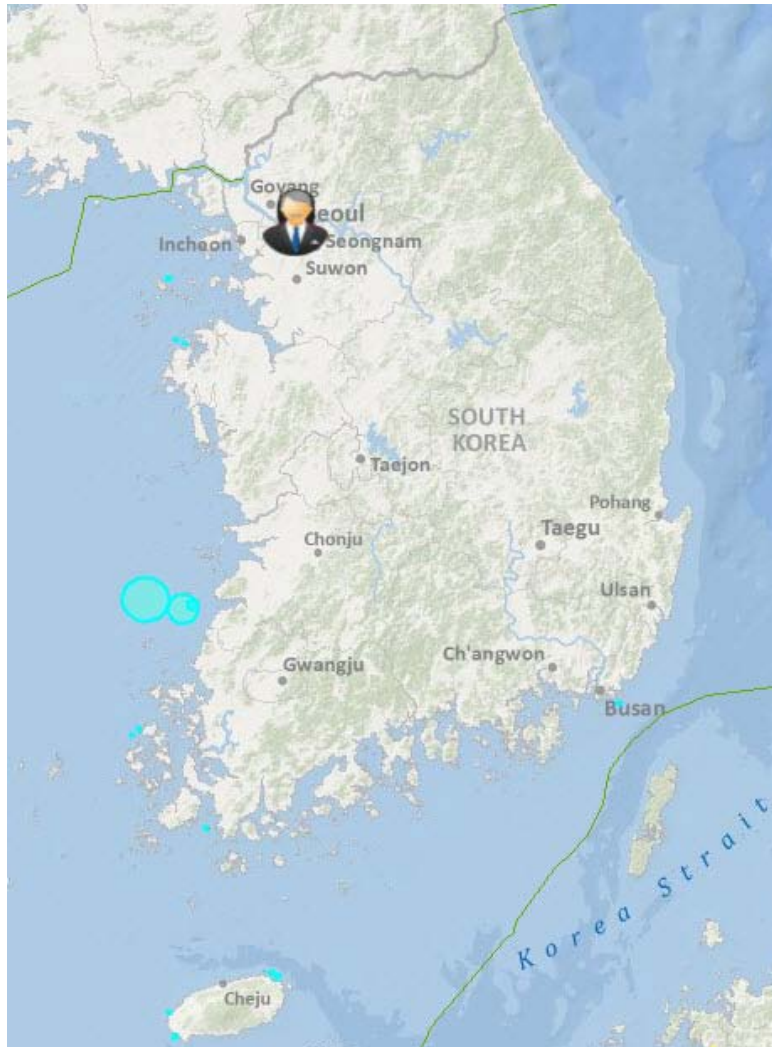
Motivation: Europe



Information on winds necessary:

- Tall offshore meteorological mast, cost 10m£
- Wind lidar on platform alternative
- Floating wind lidar?
- Satellite ocean wind observations
- Modelling (microscale and/or mesoscale)

Motivation: South Korea



Windfarm Data		
17 Windfarms found		<input type="button" value="Search Again"/>
Windfarms		
Busan		
	Country:	South Korea
	WindfarmStatus:	Concept/Early Planning
	CapacityMW:	350
Daejeong - Phase 1		
	Country:	South Korea
	WindfarmStatus:	Concept/Early Planning
	CapacityMW:	100
Daejeong - Phase 2		
	Country:	South Korea
	WindfarmStatus:	Concept/Early Planning
	CapacityMW:	100
Stakeholders		

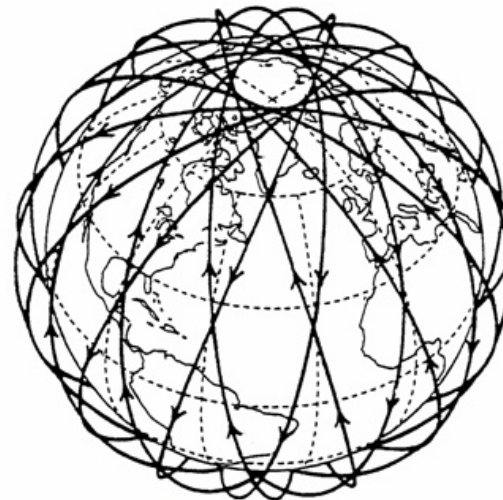
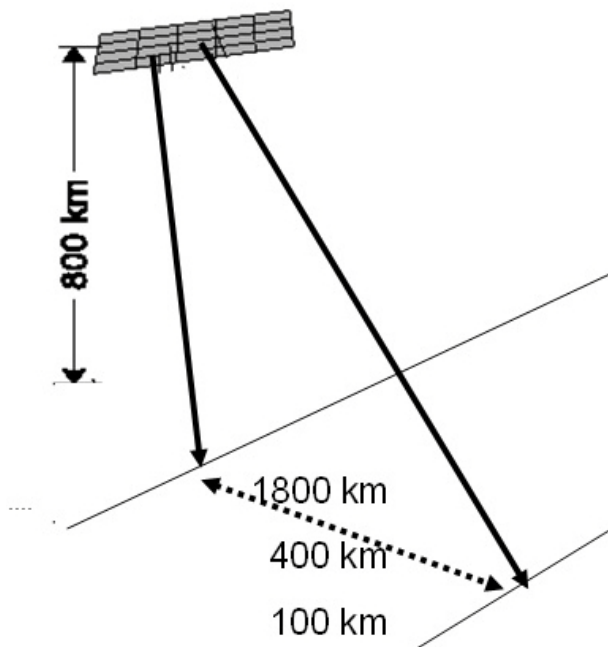
17 offshore wind farm projects with
sum of 4 GW offshore capacity

Source: <http://www.4coffshore.com/offshorewind/>

South Korea offshore wind farm plans

Wind farm	MW	Concept/early planning	Consent application sent	Under construction	Fully commissioned
Busan	350	1			
Daejeong-Phase 1	100	1			
Daejeong-Phase 2	100	1			
Dongyang	27	1			
Haengwon-ri	60	1			
Hall E&Offshore wind 1	100	1			
Hall E&Offshore wind 2	200	1			
Incheon Offshore Wind Farm	97.5	1			
Limjado	100	1			
Shinan	90	1			
Southwest Offshore Wind project 1 (test)	100	1			
Southwest Offshore Wind project 2	400	1			
Southwest Offshore Wind project 3	2000	1			
Taeon 1	97.2		1		
Taeon 2	200	1			
Tamra Offshore Wind Farm	30			1	
Demo Jeju Island	5				1

Satellite principle - radar



The orbit of -

ASCAT

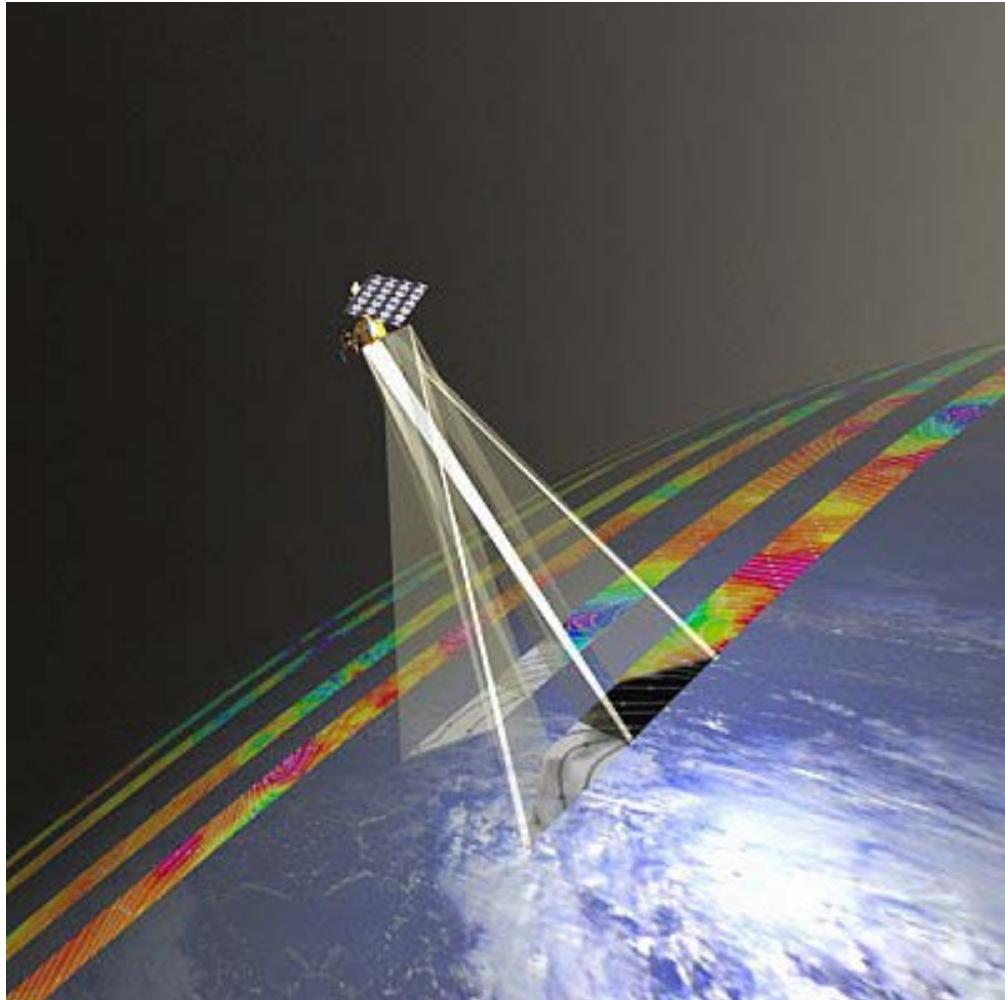
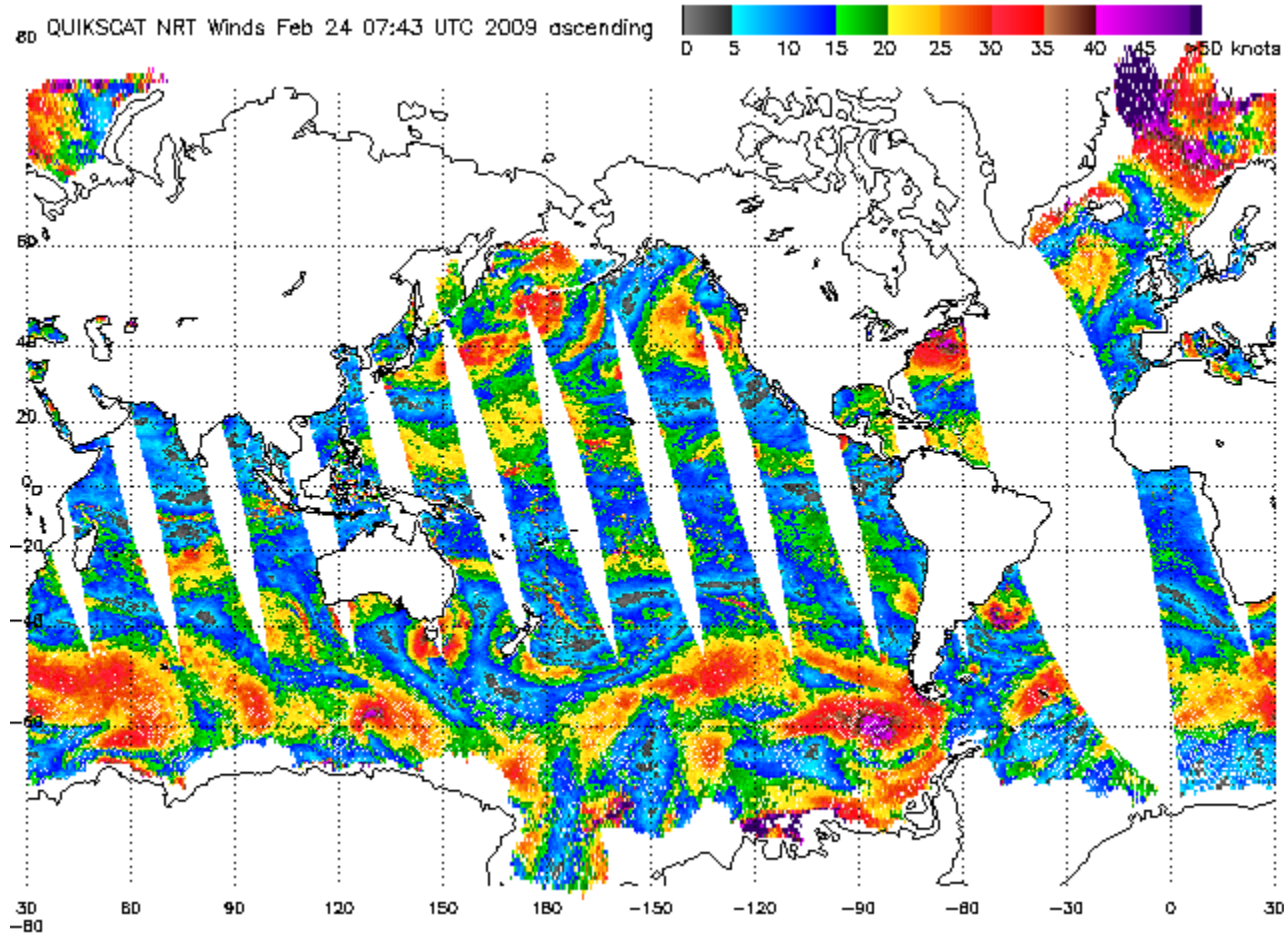
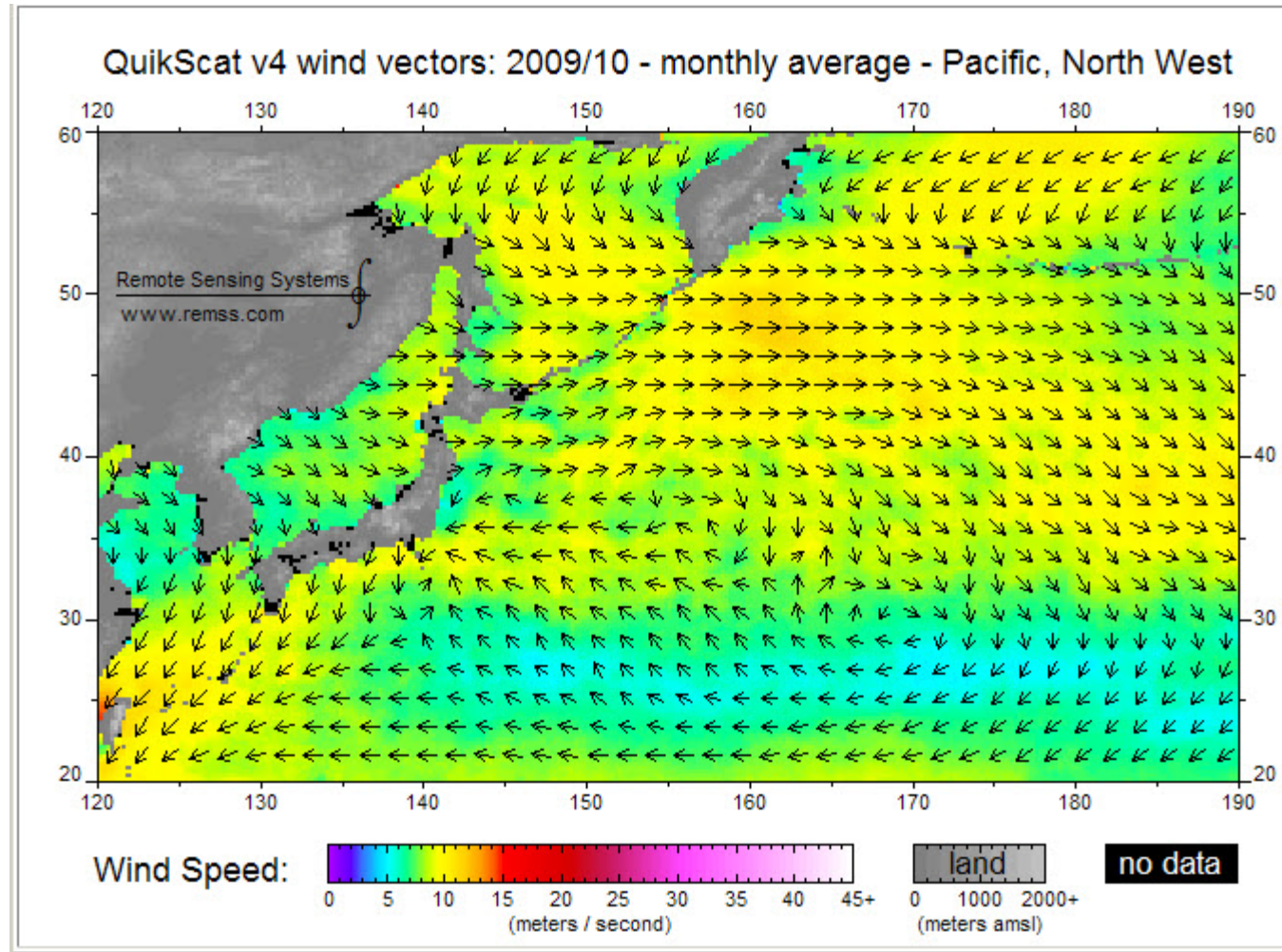


Image from ESA

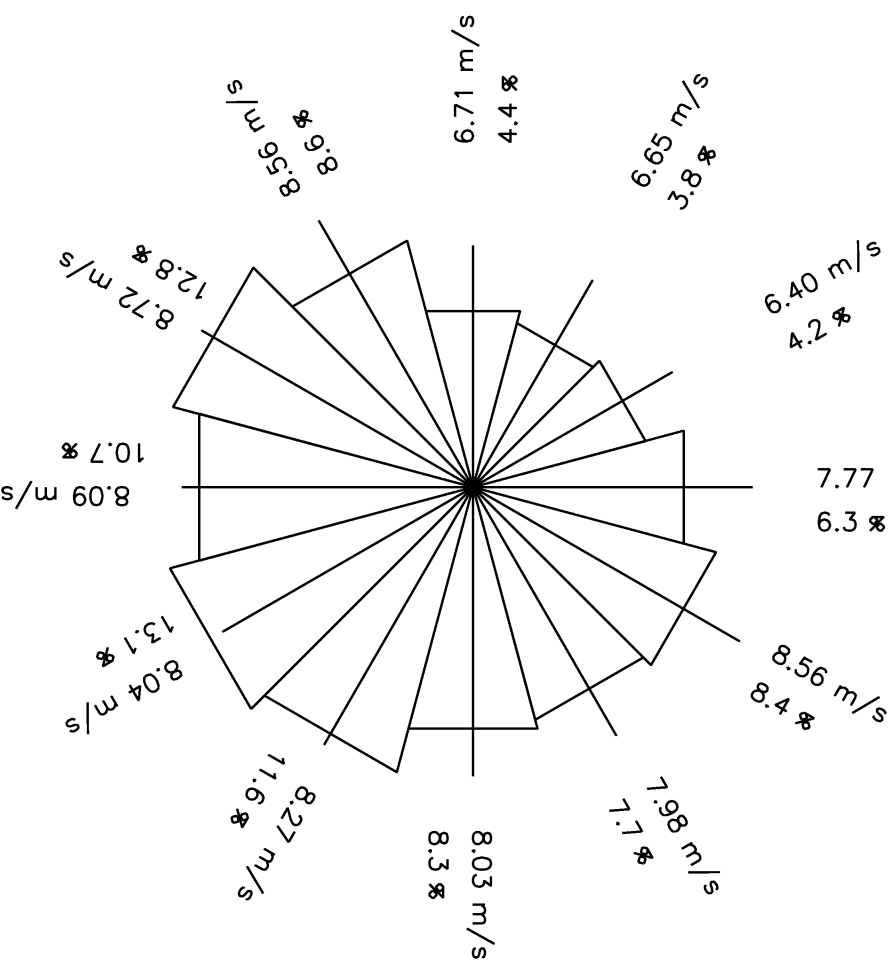
Scatterometer winds (QuikSCAT)



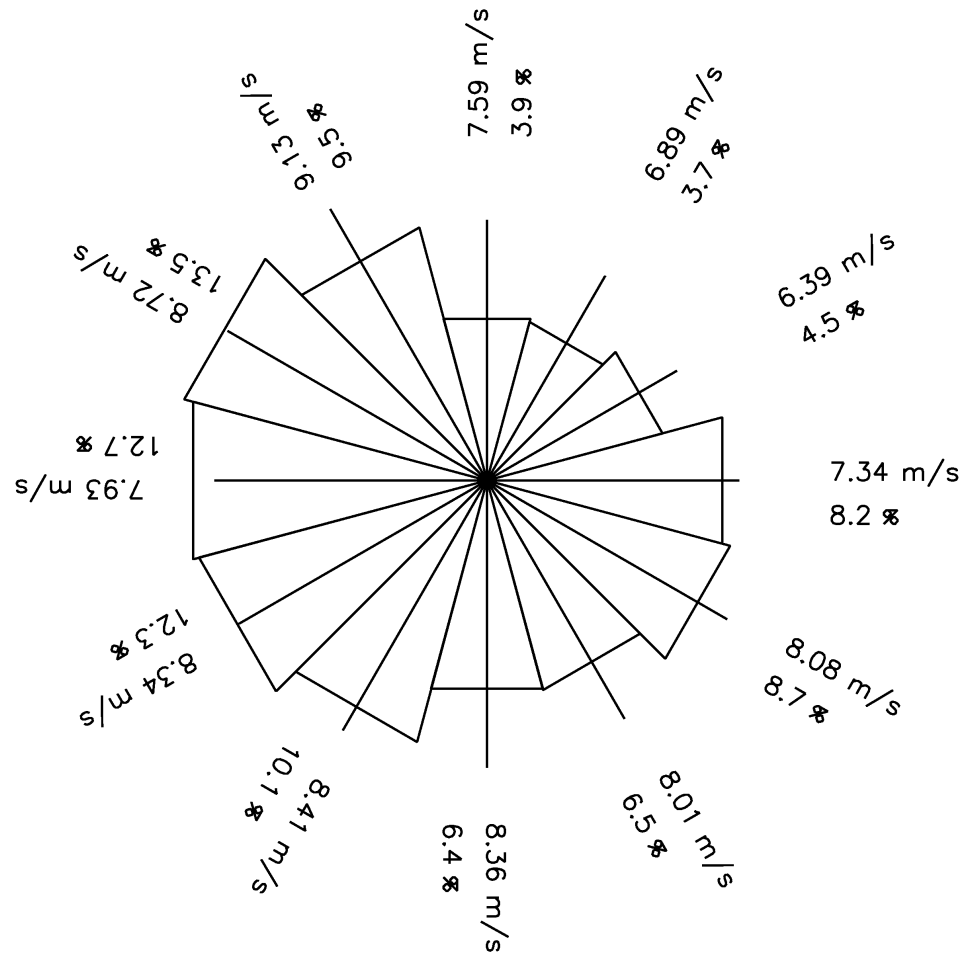
Monthly example from Pacific North West



Example mast and QuikSCAT at Horns Rev



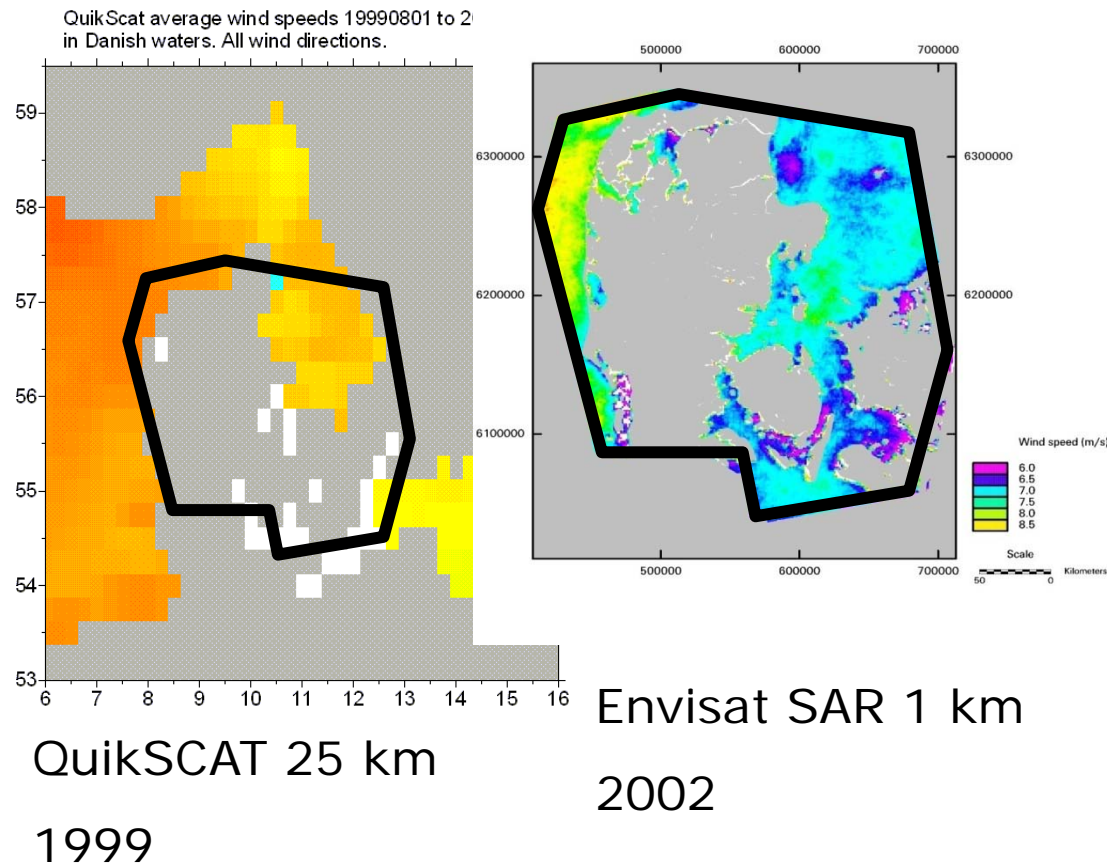
Mast data courtesy DONG energy



QuikSCAT

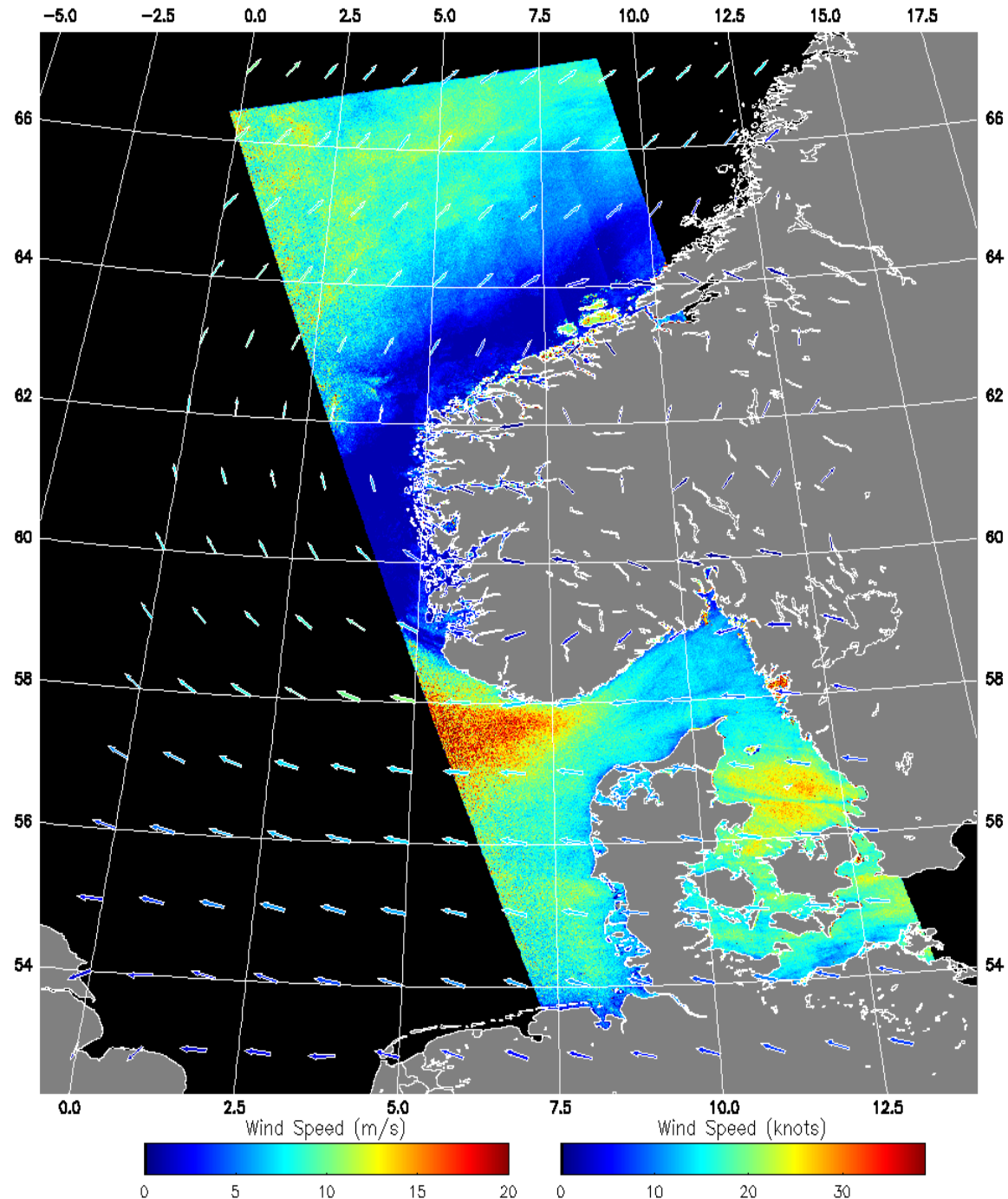
From Hasager et al. 2008 IEEE TGARS , vol. 1, 67-79.

QuikSCAT and Envisat ASAR resolution and coastal

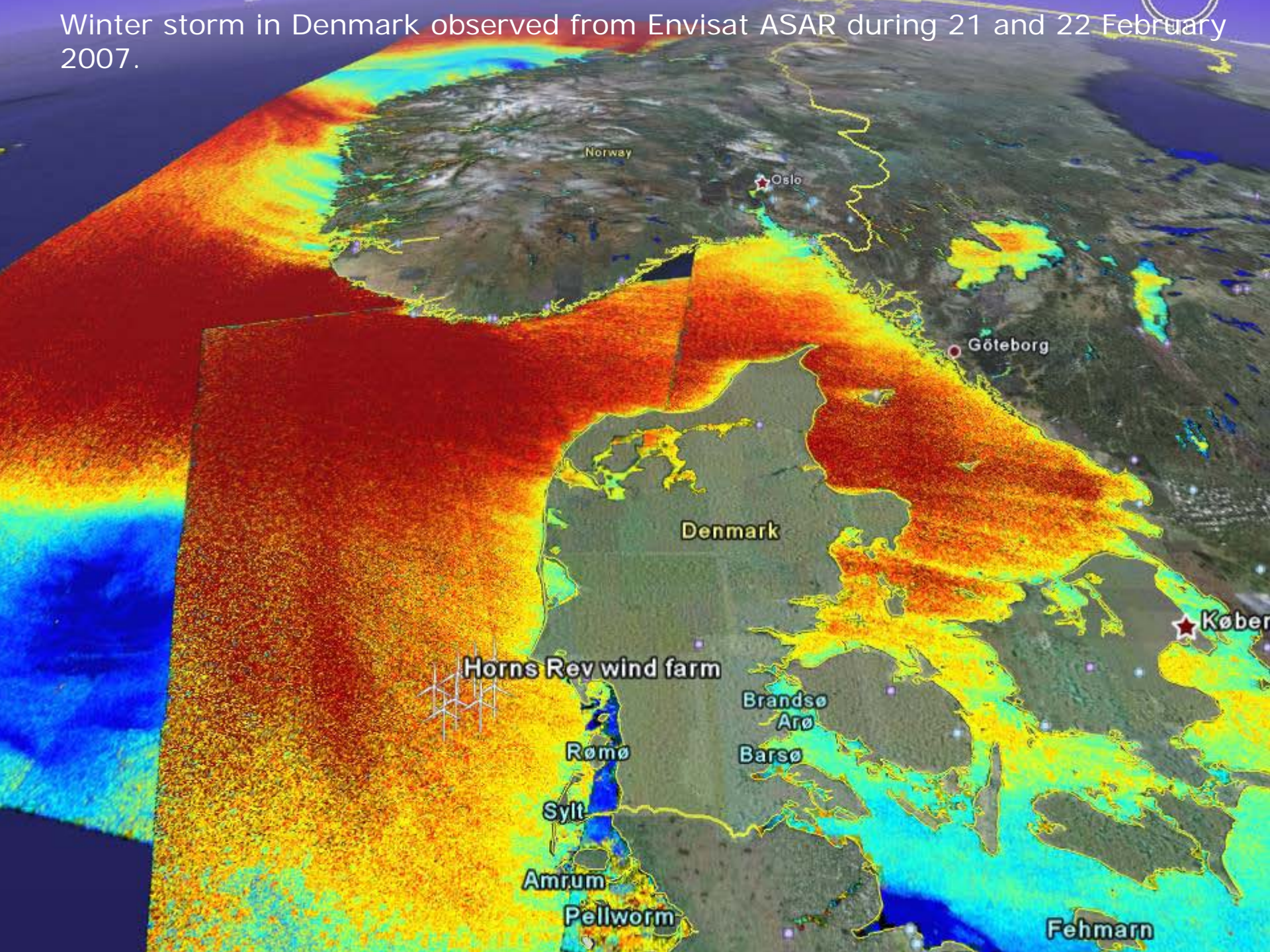


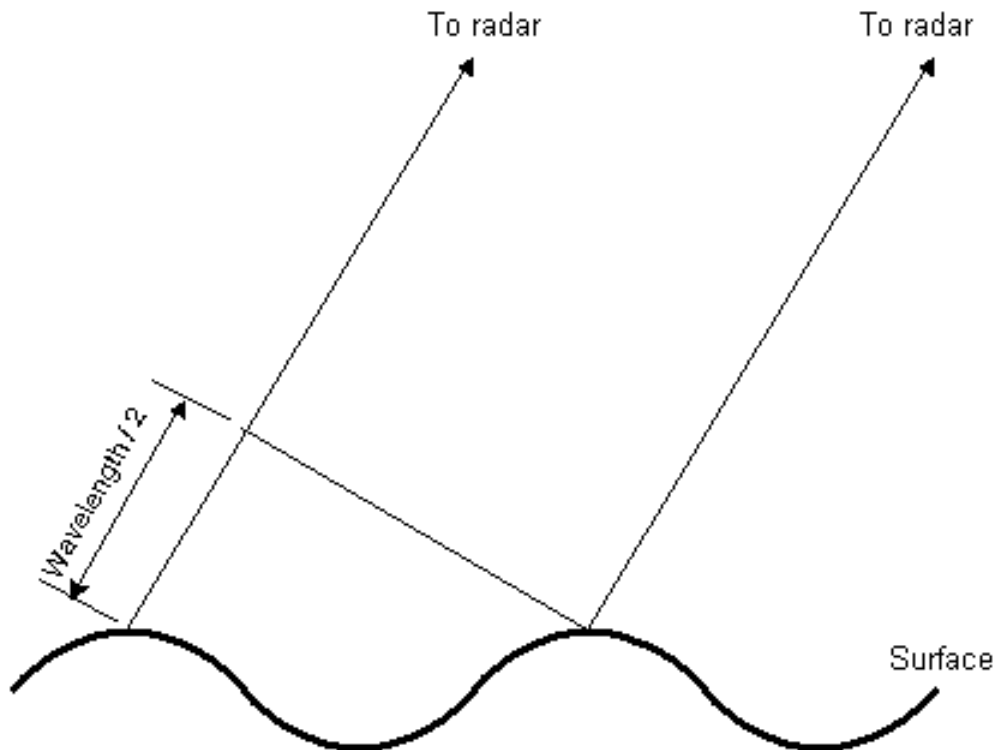
Satellite SAR wind map

- Wind map covering Danish and southern Norwegian Seas based on Envisat ASAR WSM from 2006/09/16 at 20:56:41 UTC DTU Wind Energy/ JHU APL.



Winter storm in Denmark observed from Envisat ASAR during 21 and 22 February 2007.





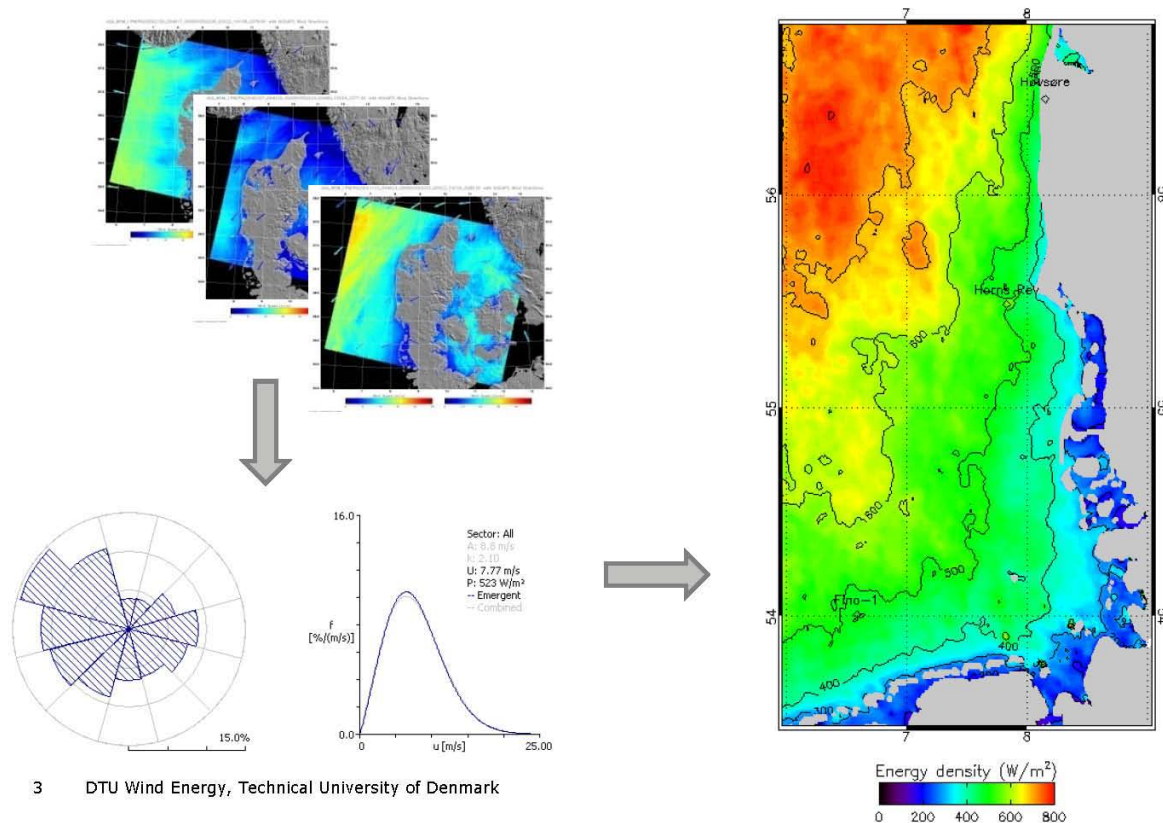
Physics

Ocean surface roughens
by wind interaction:
Capillary and short gravity
waves are generated.

More wind causes more
steep waves causes
higher backscatter.

Offshore wind resource method

Wind resource mapping from satellite wind fields

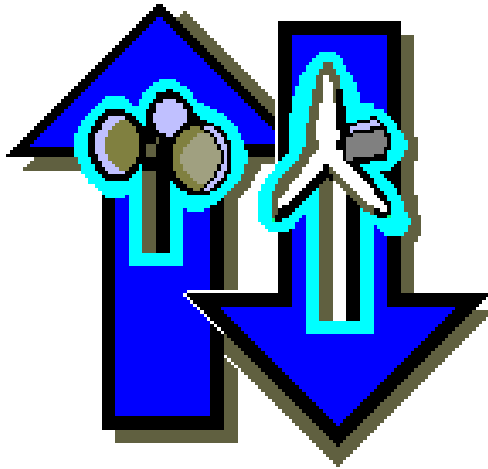


3 DTU Wind Energy, Technical University of Denmark

Results comparing SAR and three met masts

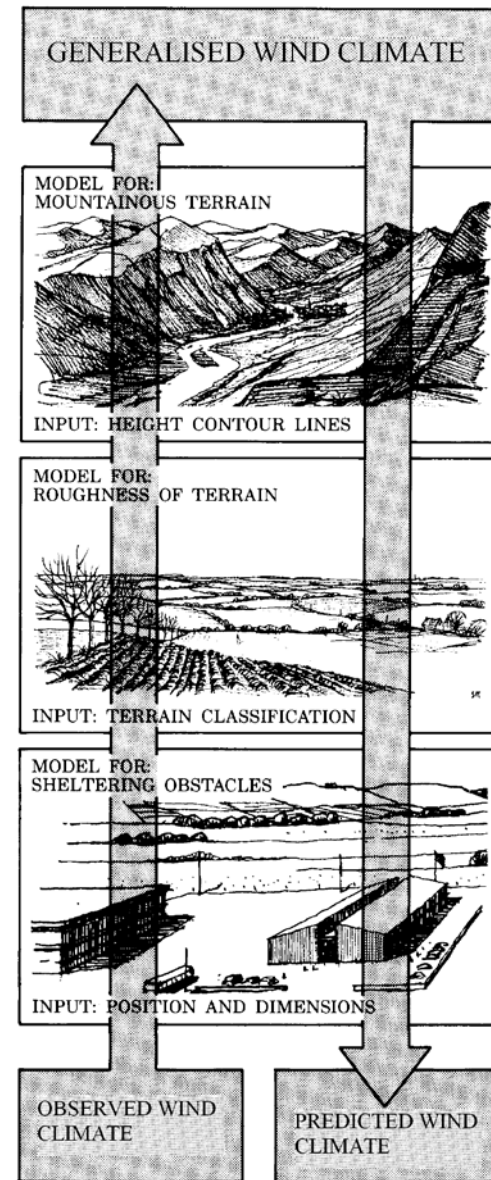
- Detailed wind resource maps have been produced over a domain in the North Sea and compared to measurements at three sites in 4-yr period (2005-2008). The accuracy on mean wind speed and Weibull A was below 5% and below 7% for Weibull k and energy density.
- The model results from mesoscale modelling are typically around 5 to 15%.
- Reference:
- Badger et al. 2010, Wind class sampling of satellite SAR imagery for offshore wind resource mapping, J.Applied Meteorology and Climatology, 49, 2474-2491.

WAsP

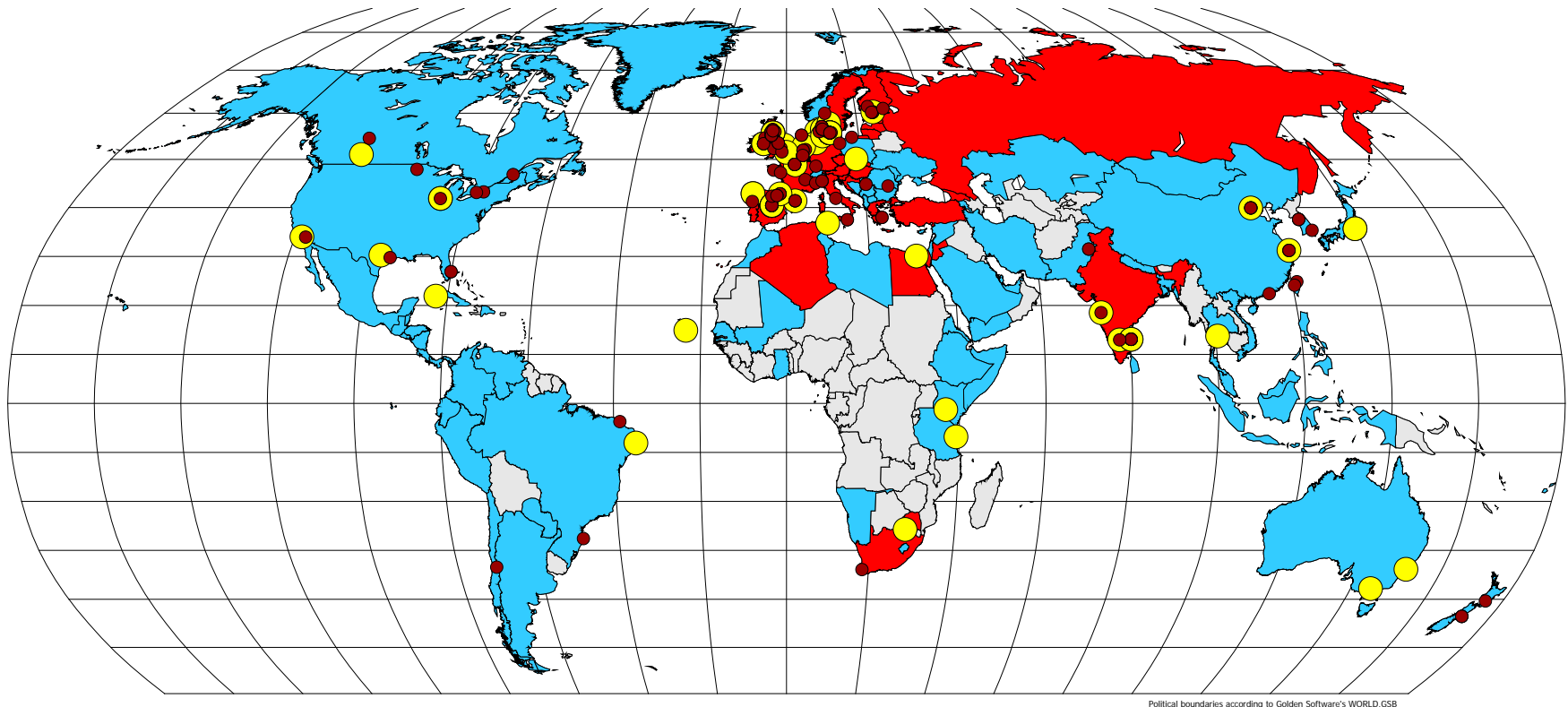


WAsP icon

www.wasp.dk



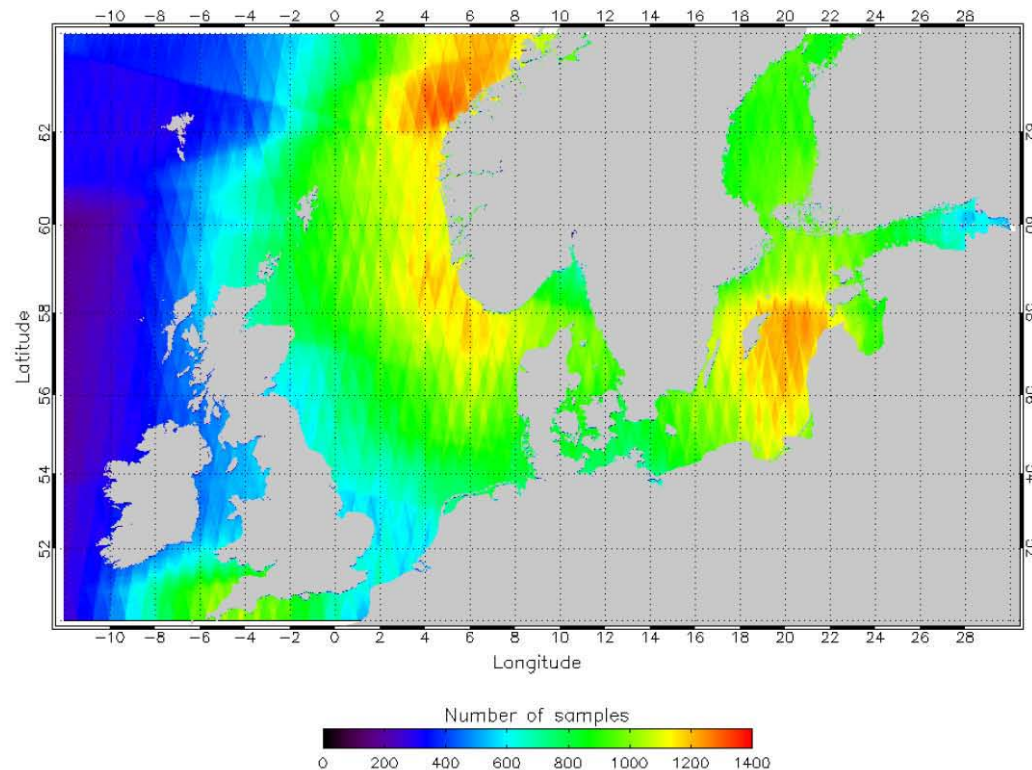
DTU Wind Energy: WAsP & WAsP Engineering



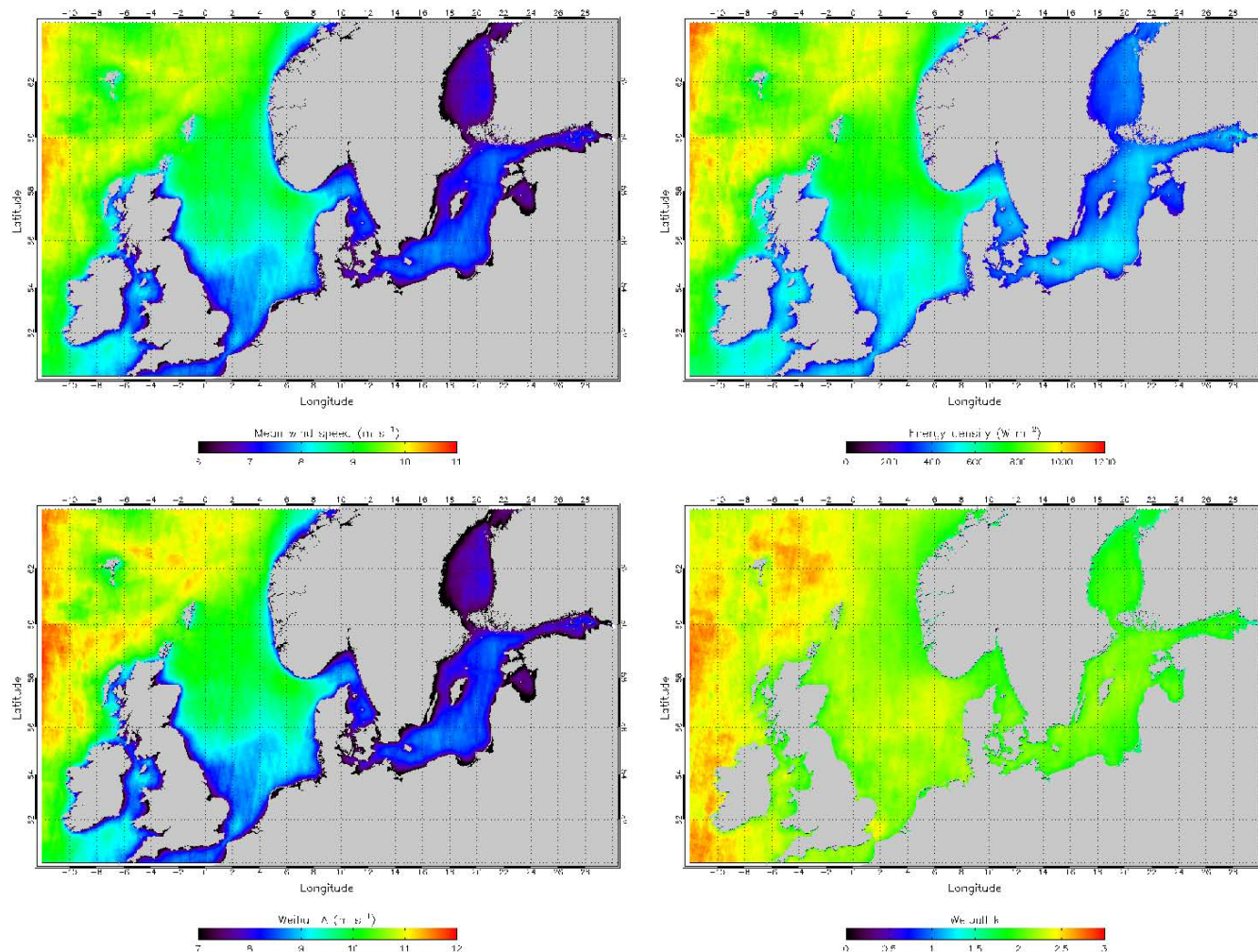
- WAsP/WEng software since 1987/2001
- More than 4000 licensed users
- Used in 110+ countries and territories
- WAsP/WEng courses since 1991/2001
- More than 100 courses in 25 countries ●
- 186 certified WAsP users in 27 countries ●

Example Northern European Seas

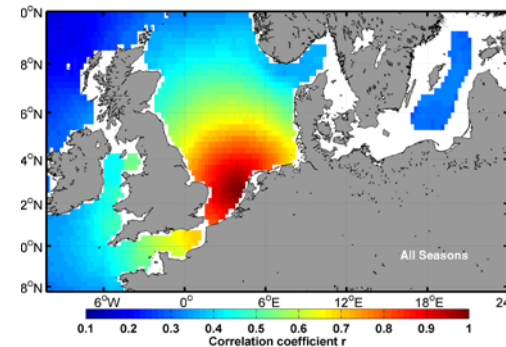
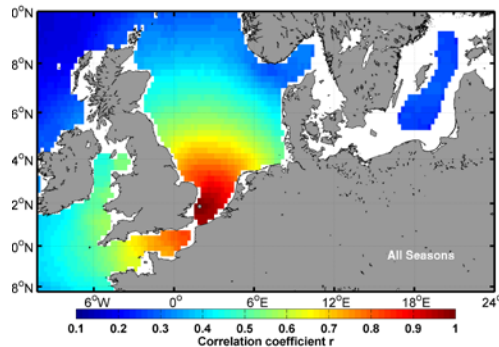
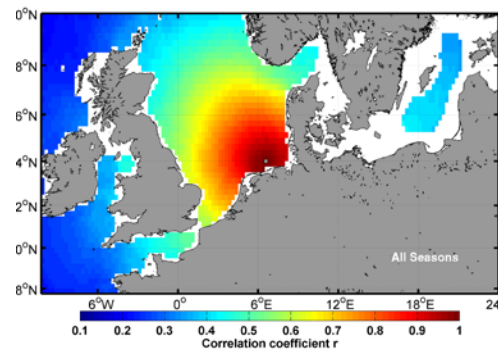
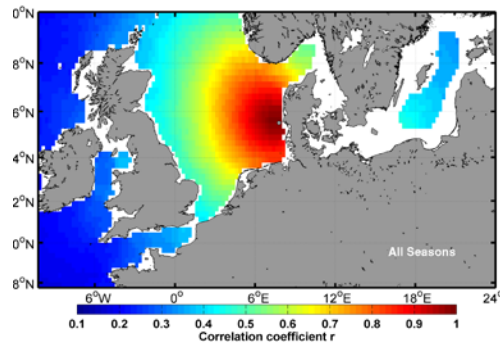
**Envisat ASAR scenes in the NORSEWInD project
- and the 10-m wind atlas from SAR**



Northern European Seas from EU Norsewind project



QuikSCAT – spatial correlations



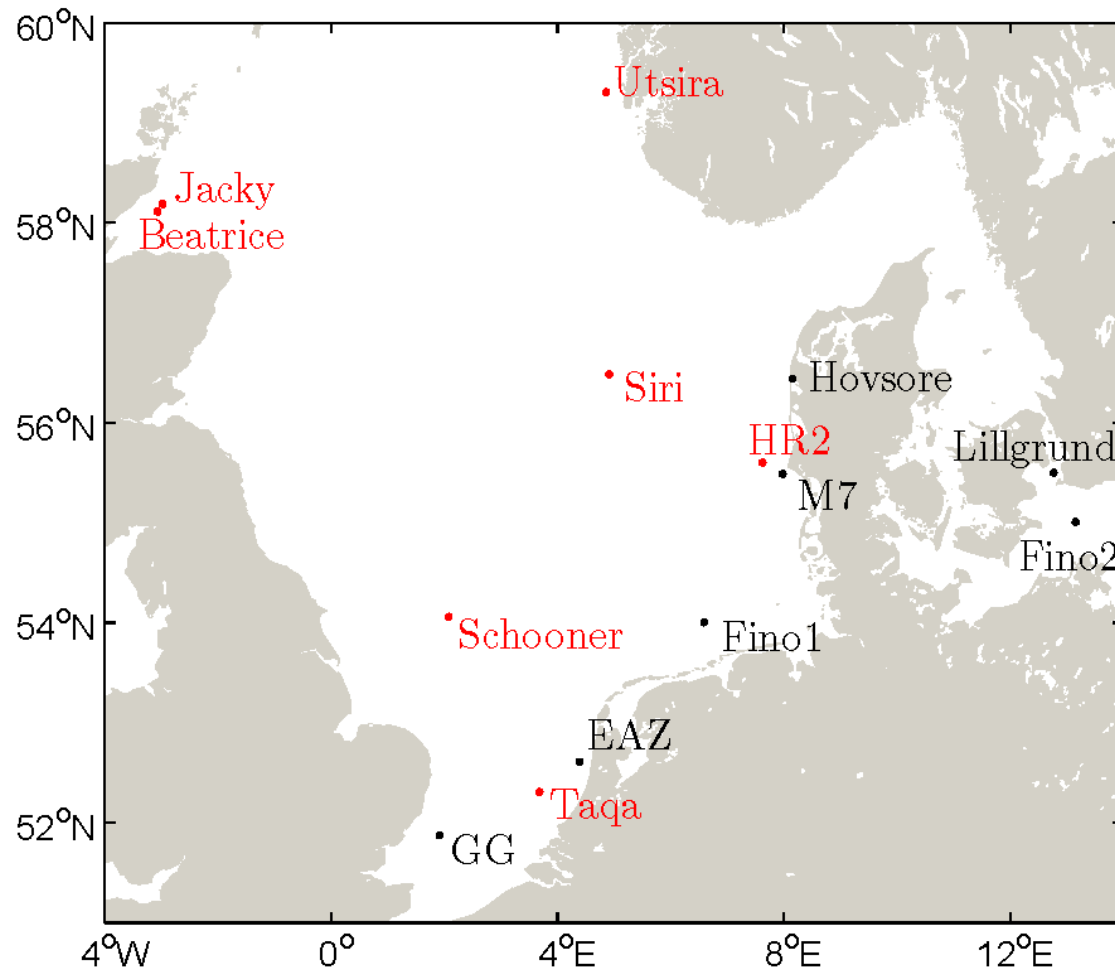
Horns Rev M2

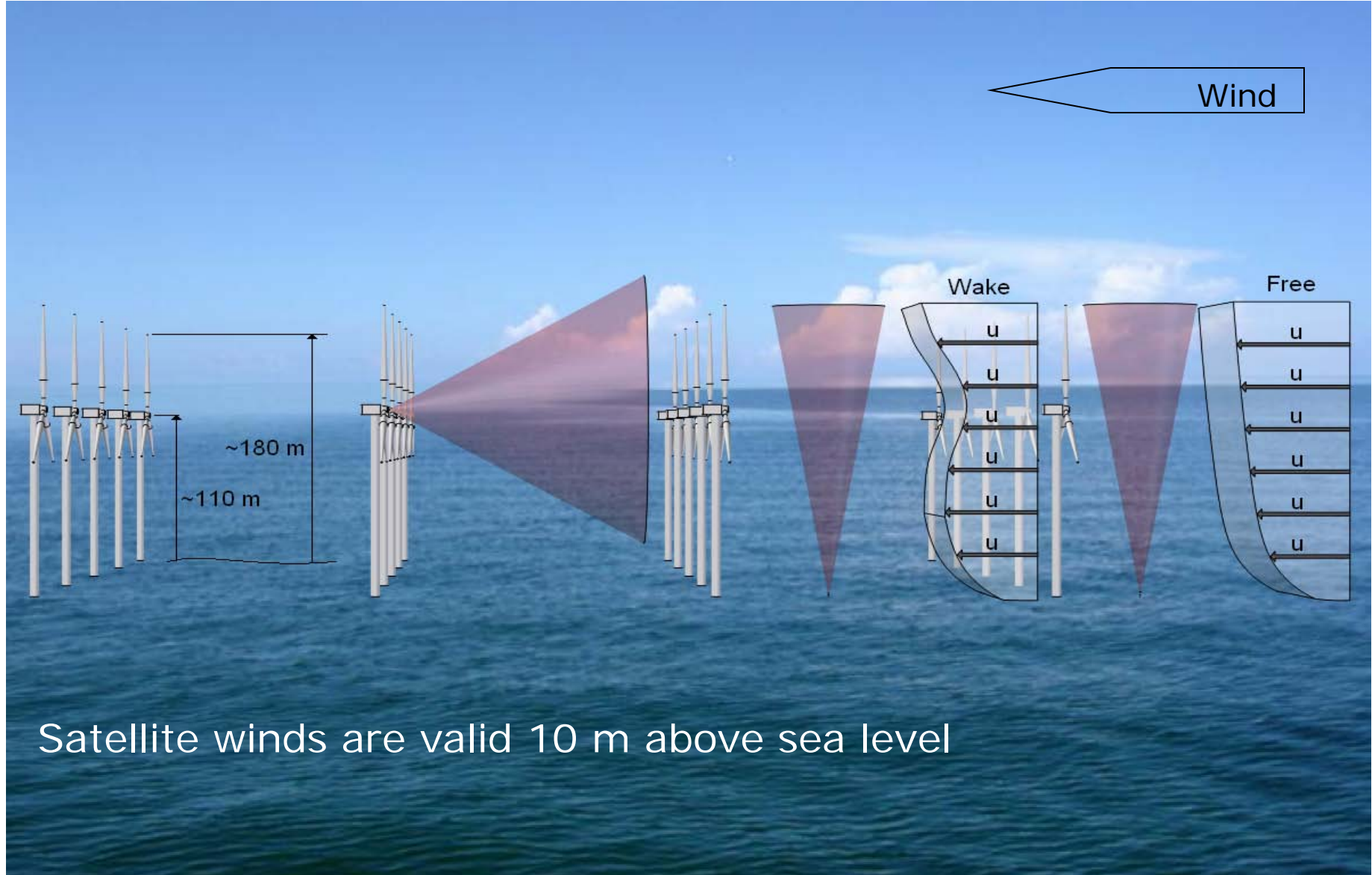
FINO-1

Egmond aan Zee

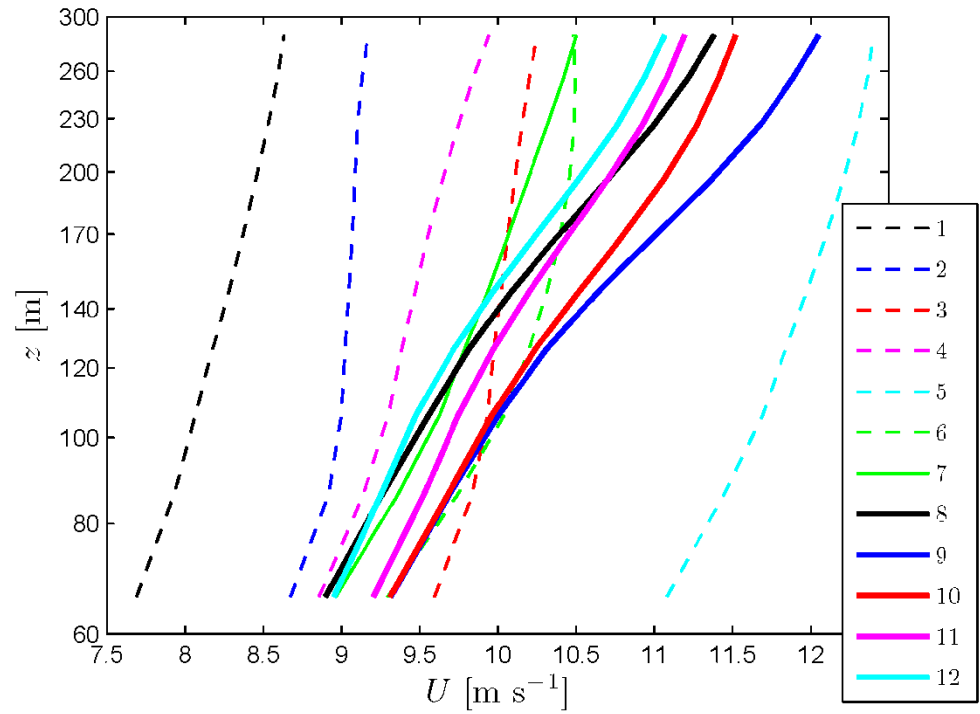
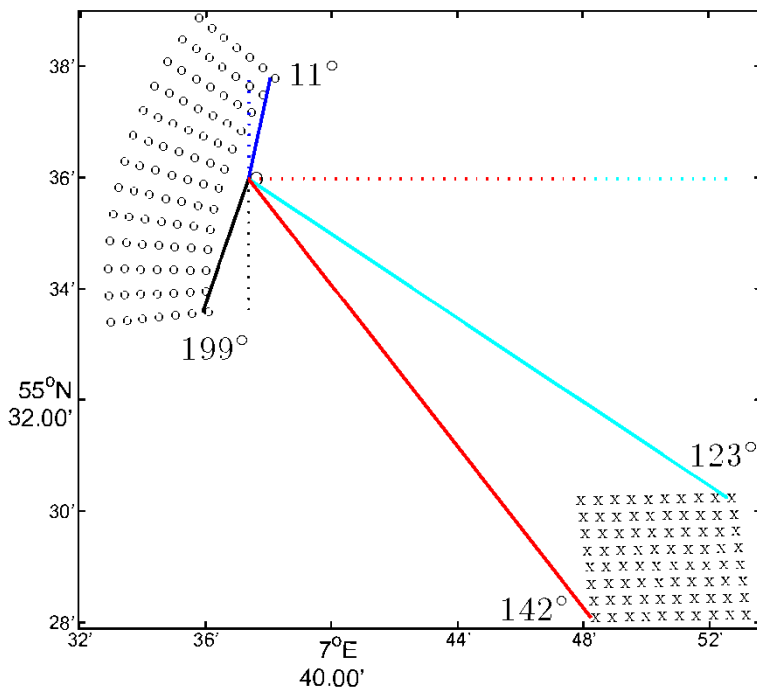
Greater Gabbard.

Norsewind installations





Horns Rev: layout and wind profiles from lidar



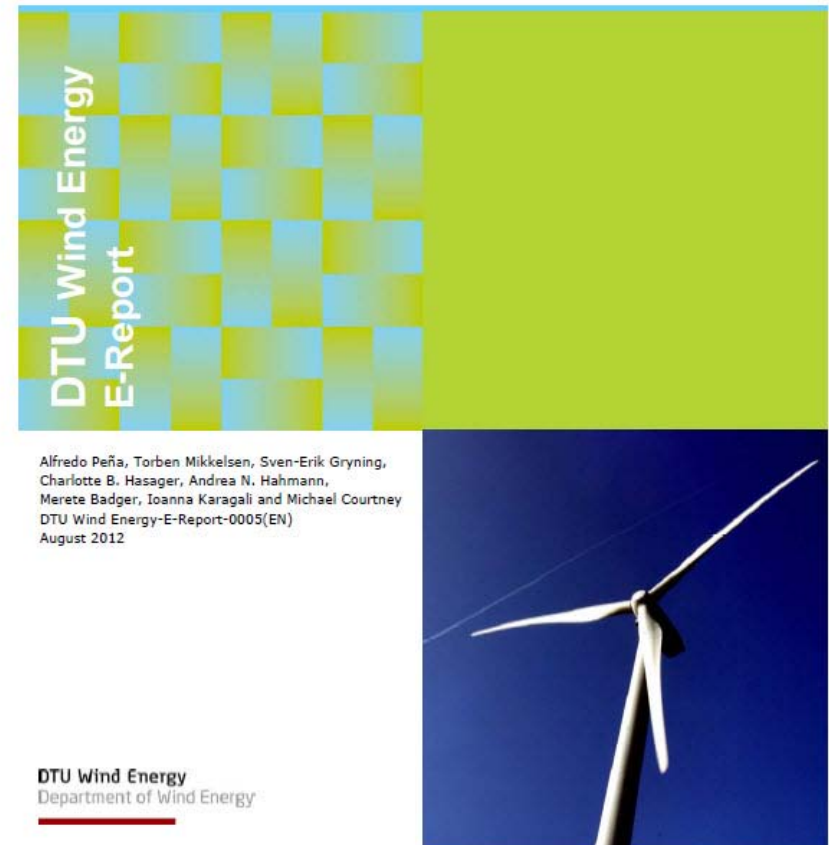
Courtesy data: DONG energy, analysis Alfredo Peña, DTU Wind Energy

Two recent reports from DTU Wind Energy



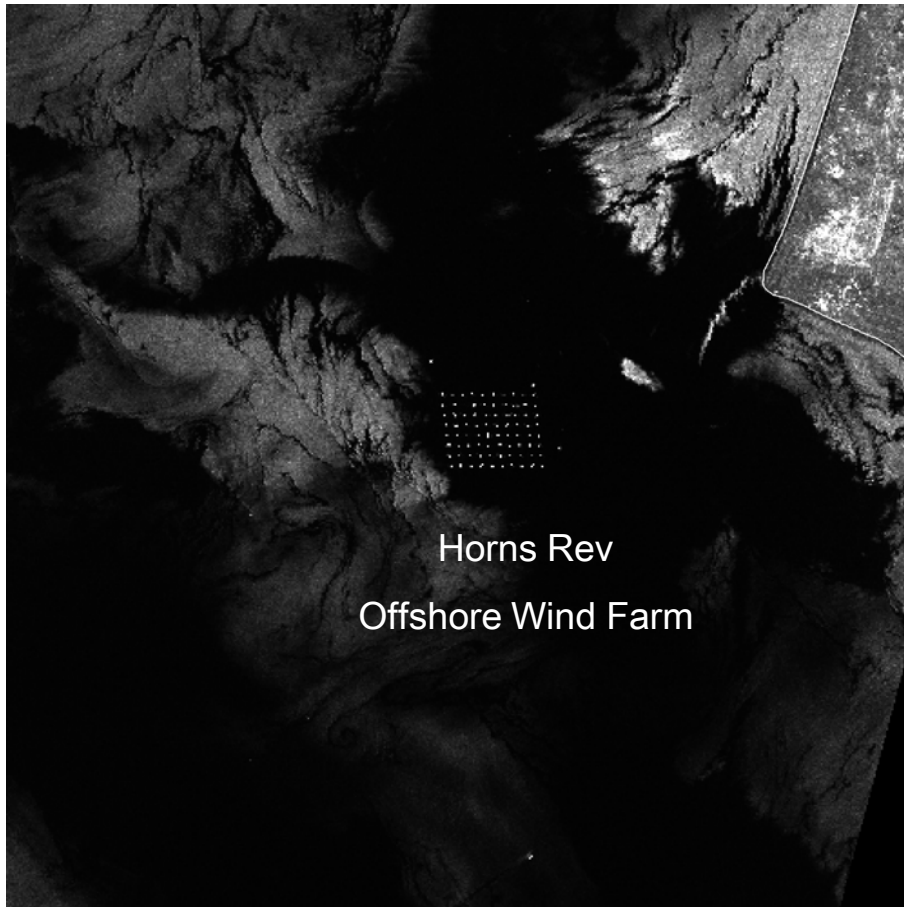
Offshore Vertical Wind Shear

Final report on NORSEWIND's work task 3.1

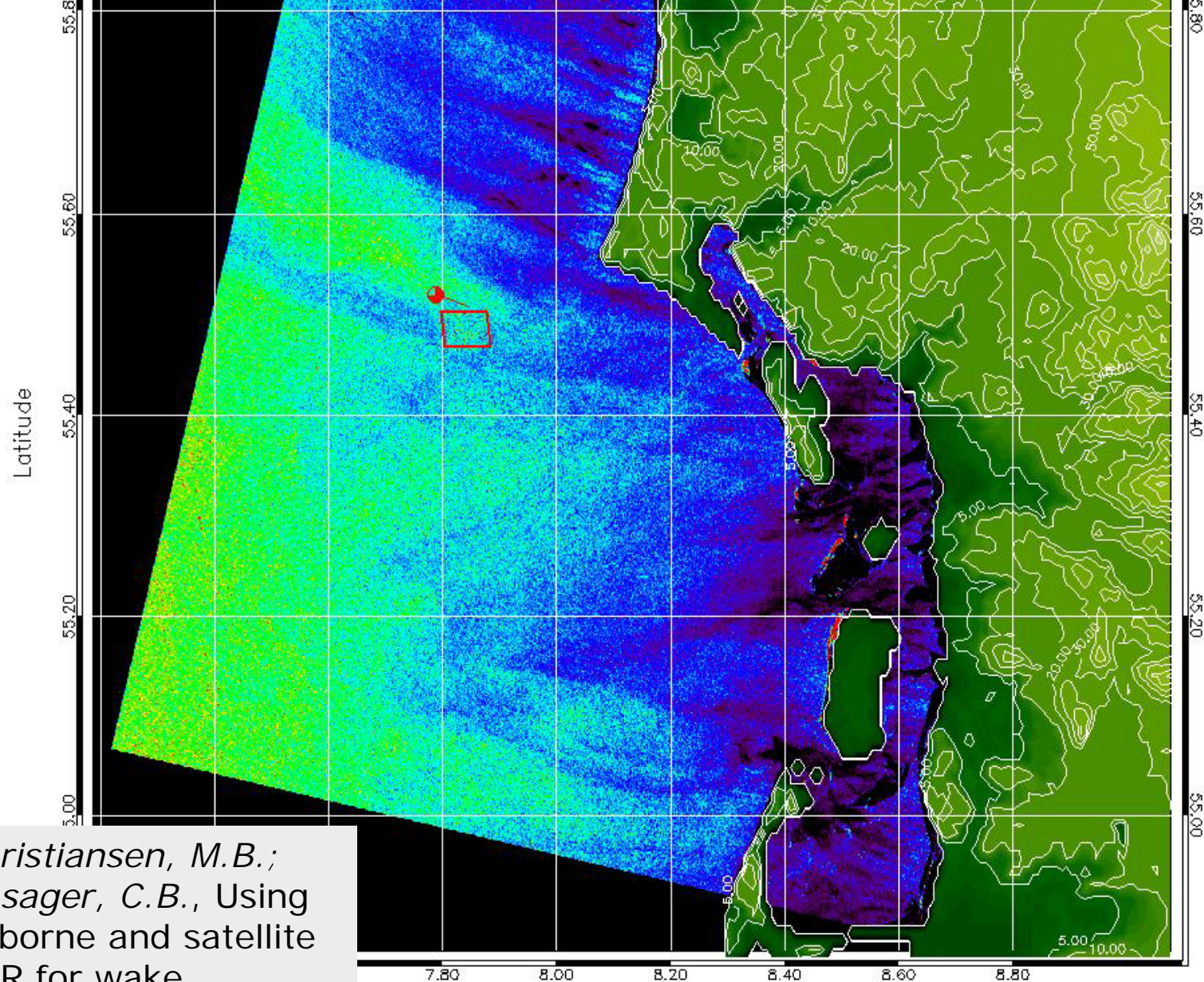


Wind farm wake

Wind farms seen from satellite



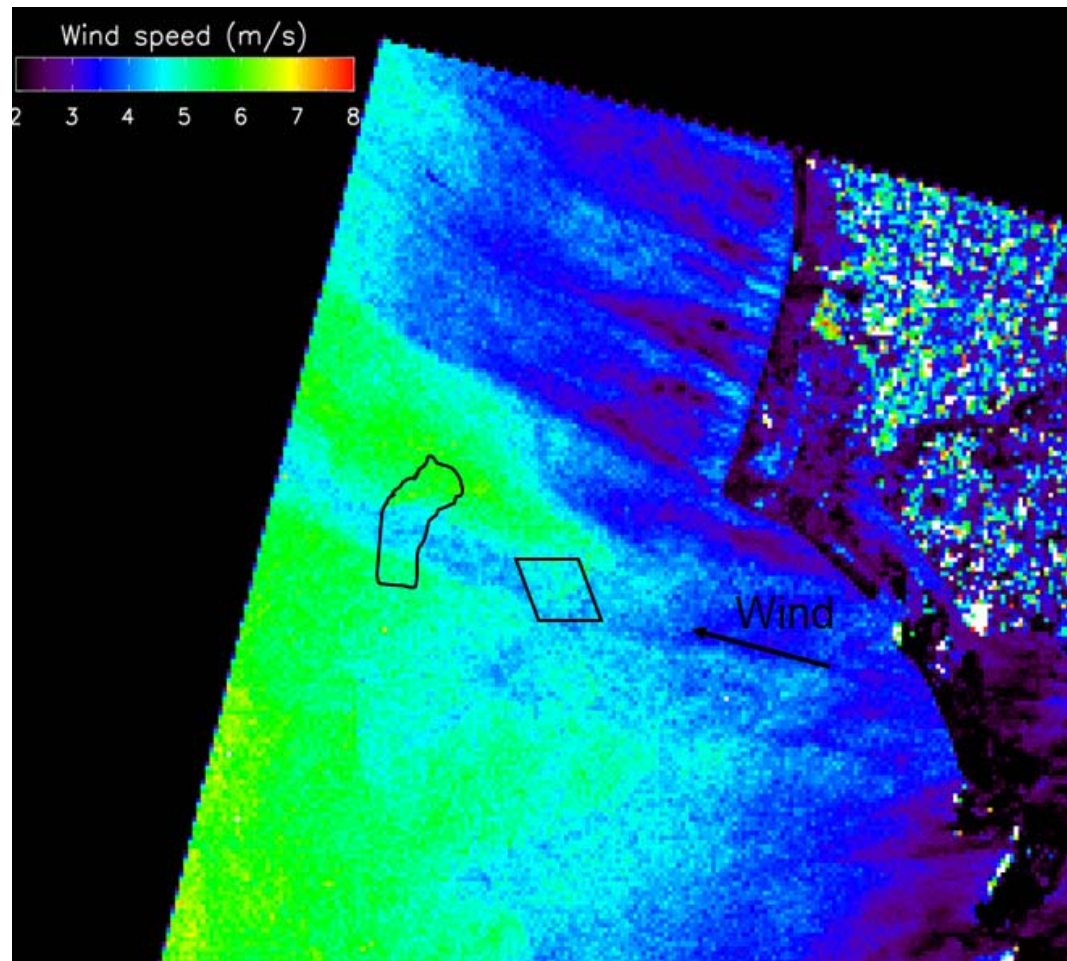
ERS-2 images, 50 km x 50 km (no wind)



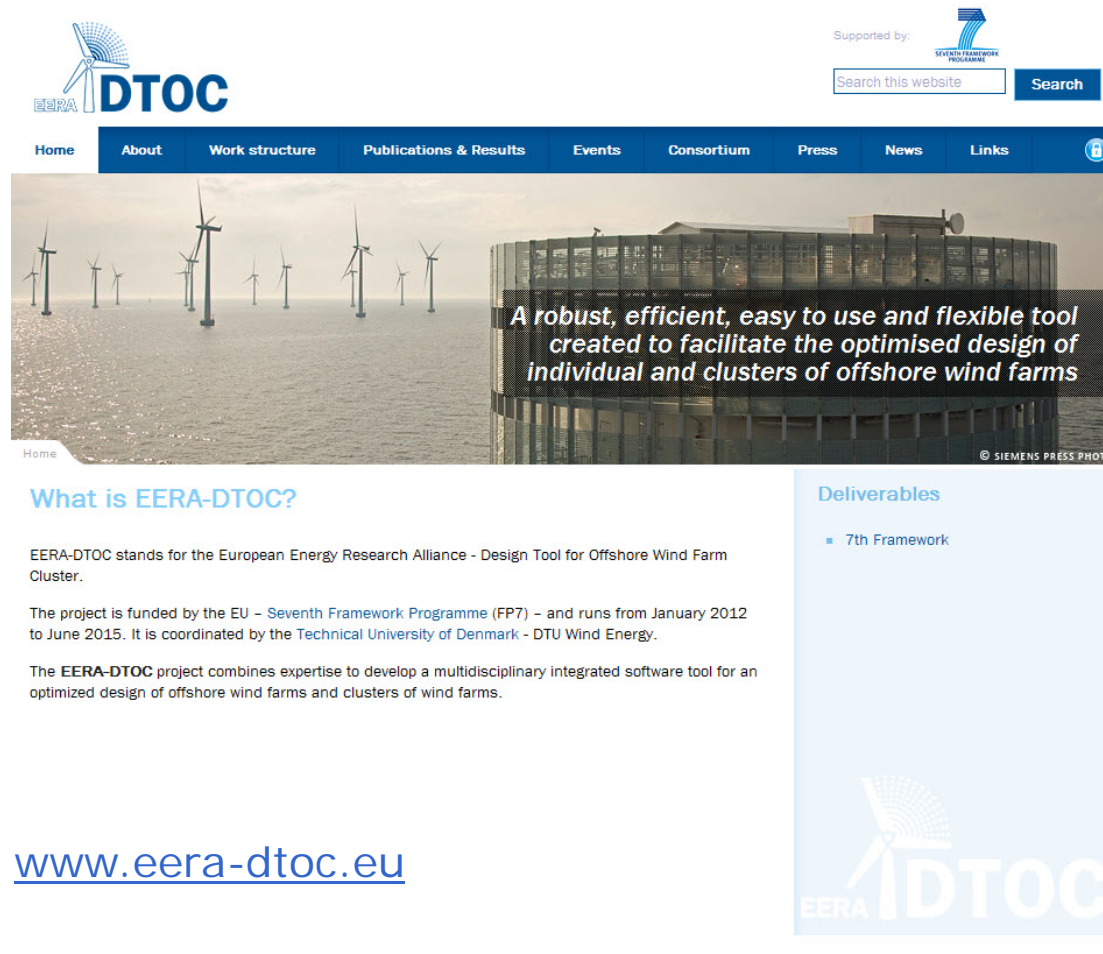
Christiansen, M.B.;
Hasager, C.B., Using
airborne and satellite
SAR for wake
mapping offshore.
Wind Energy (2006) **9**
437-455

Wind field from ERS-2 SAR

Wind farm wake – two wind farms?



Design Tools for Offshore wind farm Clusters



The screenshot shows the EERA-DTOC website. At the top left is the EERA-DTOC logo. To the right, it says 'Supported by:' followed by the '7th Framework Programme' logo. Below this is a search bar with the text 'Search this website' and a 'Search' button. A navigation menu includes links for Home, About, Work structure, Publications & Results, Events, Consortium, Press, News, and Links. The main banner features a photograph of an offshore wind farm with a large circular platform in the foreground. Overlaid on the image is the text: 'A robust, efficient, easy to use and flexible tool created to facilitate the optimised design of individual and clusters of offshore wind farms'. Below the banner, the 'What is EERA-DTOC?' section explains that EERA-DTOC stands for the European Energy Research Alliance - Design Tool for Offshore Wind Farm Cluster, funded by the EU - Seventh Framework Programme (FP7) from January 2012 to June 2015, coordinated by DTU Wind Energy. It also states that the project combines expertise to develop a multidisciplinary integrated software tool. To the right, the 'Deliverables' section lists the '7th Framework'. At the bottom right is a large EERA-DTOC logo.

What is EERA-DTOC?

EERA-DTOC stands for the European Energy Research Alliance - Design Tool for Offshore Wind Farm Cluster.

The project is funded by the EU - [Seventh Framework Programme \(FP7\)](#) - and runs from January 2012 to June 2015. It is coordinated by the [Technical University of Denmark](#) - DTU Wind Energy.

The **EERA-DTOC** project combines expertise to develop a multidisciplinary integrated software tool for an optimized design of offshore wind farms and clusters of wind farms.

Deliverables

- 7th Framework

www.eera-dtoc.eu

Summary

- Scatterometer ocean vector winds from QuikSCAT and ASCAT are medium resolution and not very close to coasts but long-term data set
- Satellite SAR ocean vector winds from Envisat and later Sentinel-1 (ESA/EU)
- Lifting of winds from 10 m to hub-height – research in progress
- Wind farm wake observed from satellite will be used in EERA-DTOC project to compare to wind farm wake model results